LESSON 17: Balloon Rockets

ESTIMATED TIME **Setup:** 5–10 minutes | **Procedure:** 5–10 minutes

DESCRIPTION

Apply the concepts of pressure and Newton's laws of motion to build simple rockets.

OBJECTIVE

This lesson demonstrates the basic principles of rocketry by applying the concept of pressure and Newton's Second and Third Laws of Motion. Students use a balloon to explore these concepts. The lesson can be extended to introduce the concepts of drag and power.

CONTENT TOPICS

Scientific inquiry, measurement; force (pressure)

It is best to use long, thin balloons for this experiment.

MATERIALS

- ❑ Balloons
- ❑ Straws
- ❑ String
- ❑ Permanent marker
- ❑ Cargo (paper clips, bottle caps, candy, etc.)
- ❑ Cereal boxes, construction paper, or any other material to make lightweight cargo containers
- ❑ Tape, glue, scissors, and any other materials needed for construction

Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the ***Safety First*** section in the ***Resource Guide*** on pages 421–423 for more detailed information about safety in the classroom.

Jump ahead to page 212 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from "A Framework for K–12 Science Education," established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS2.A: Forces and Motion
- PS2.C: Stability and Instability in Physical Systems
- PS3.C: Relationship Between Energy and Forces
- ETS1.A: Definiting and Delimiting an Engineering Problem (see ***Analysis & Conclusion***)
- ETS1.B: Developing Possible Solutions (see ***Analysis & Conclusion***)
- ETS1.C: Optimizing the Design Solution (see ***Analysis & Conclusion***)
- ETS2.A: Interdependence of Science, Engineering, and Technology (see ***Analysis & Conclusion***)

OBSERVATION & RESEARCH

BACKGROUND

Rocketry has existed for hundreds of years. Although the technology has greatly improved and there are numerous methods for propelling a rocket, the simple science behind rockets has always been the same. To propel a rocket, some kind of force must be expelled from the rocket in order to push it forward. A force is the amount of push or pull on an object. The mechanical force that pushes a rocket or aircraft through the air is known as thrust.

Two of Newton's laws of motion relate to force, and therefore, relate to thrust. Newton's Second Law of Motion states that the relationship between an object's mass (m), its acceleration (a), and the applied force (F) is **F = ma**. For example, the force of a basketball pushed toward the ground is equal to the mass of the ball

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multiplied by the acceleration of the ball toward the ground. **Newton's Third Law of Motion** states that for every action there is an equal and opposite reaction. For example, when a basketball is pushed toward the ground, the force with which the basketball hits the ground is oppositely and equally applied back to the ball by the ground. As a result, the ball bounces back upward.

In this experiment, the rocket is propelled by pressure. **Pressure** is the amount of force exerted on an area. When you blow up the balloon, you are filling the balloon with gas particles (mainly oxygen). The gas particles move freely within the balloon and may collide with one another. As more gas is added to the balloon, the number of gas particles in the balloon increases, as well as the number of collisions. While the force of a single gas particle collision is too small to notice, the total force created by all of the gas particle collisions within the balloon is significant. As the number of collisions within the balloon increases, so does the pressure within the balloon.

In addition, the pressure of the gas inside the balloon becomes greater than the air pressure outside of the balloon. The pressure inside the balloon serves as the fuel for the rocket. When you release the opening of the balloon, gas quickly escapes to equalize the pressure inside with the air pressure outside of the balloon. As the air escapes from the balloon, it exerts a force on the ground and the air outside of the balloon. According to Newton's Third Law of Motion, as the gas is released from the balloon and pushes against the outside air, the outside air pushes back. As a result, the rocket is propelled forward by the opposing force. This opposing force is thrust.

FORMULAS & EQUATIONS

Newton's laws of motion have played a key role in humans' understanding of the universe.

- **Newton's First Law of Motion (the Law of Inertia) states:** Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

CONNECT TO THE *YOU BE THE CHEMIST* CHALLENGE

For additional background information, please review CEF's Challenge study materials online at http://www.chemed.org/ybtc/challenge/study.aspx.

- Additional information on scientific laws can be found in the Science—A Way of Thinking section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on types of measurements, including force and pressure, can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on states of matter can be found in the in Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

- **Newton's Second Law of Motions states:** The acceleration (a) of an object as produced by a net force is directly proportional to the magnitude of the net force (F), in the same direction as the net force, and inversely proportional to the mass (m) of the object. This relationship is described by the equation: **F = ma**.
- **Newton's Third Law of Motion states:** For every action, there is an equal and opposite reaction.

Pressure is the amount of force exerted on an area.

This relationship is described by the following equation: **p = F/A**.

HYPOTHESIS

▶A simple rocket made with a balloon will be propelled down a string according to Newton's laws of motion, because of thrust generated by pressure.

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DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 212 (or perform the experiment as a demonstration), and focus on gases and pressure. How do they know the pressure is increasing in the balloon? Use the amount of people in the room as an example. If more people were crammed into the room and moving around, would they feel more pressure on their bodies as they bumped into one another? Likewise, if you have marbles or similar objects available, you can instruct students to hold one marble closed in between both hands. When they shake their hands with the marble inside, they will feel the marble move around and collide with the inside of their hands. If they hold three marbles closed within both hands and shake them, do they notice a difference?

HIGHER GRADE LEVELS/ADVANCED STUDENTS

DESCRIPTION

Build simple rockets by applying the concepts of pressure and Newton's laws of motion.

OBJECTIVE

This lesson demonstrates the basic principles of rocketry, addressing Newton's laws of motion and the concepts of force, pressure, drag, and power.

OBSERVATION & RESEARCH

The development of flight and rocketry has led to major advances for humans, and these inventions rely on similar principles. To propel an aircraft or rocket, some kind of force must be expelled from the vehicle in order to push it forward. A **force** is the amount of push or pull on an object.

The mechanical force that pushes a rocket or aircraft through the air is known as **thrust**. On the contrary, **drag** is a mechanical force that opposes an aircraft's motion through the air. It is generated by the difference in velocity between a solid object and a **fluid** (liquid or gas). Without the presence of a fluid or without motion, there is no drag.

In this experiment, the rocket is propelled by pressure. **Pressure** is the amount of force exerted on an area. When you blow up the balloon, you are filling the balloon with gas particles (mainly oxygen). The gas particles move freely within the balloon and may collide with one another. As more gas is added to the balloon, the number of gas particles in the balloon increases, as well as the number of collisions. While the force of a single gas particle collision is too small to notice, the total force created by all of the gas particle collisions within the balloon is significant. As the number of collisions within the balloon increases, so does the pressure within the balloon.

In addition, the pressure of the gas inside the balloon becomes greater than the air pressure outside of the balloon. The pressure inside the balloon serves as the fuel for the rocket. When you release the opening of the balloon, gas quickly escapes to equalize the pressure inside with the air pressure outside of the balloon. As the gases escape from the balloon, the gas particles exert a force on the ground and the air outside of the balloon. According to Newton's Third Law of Motion, every action has an equal and opposite reaction. Therefore, as the gas is released from the balloon, it pushes against the outside air, and the outside air pushes back. As a result, the rocket is propelled forward by the opposing force. This opposing force is thrust.

In an aircraft or rocket, the engine provides power to the propeller, which produces the thrust. **Power** is the rate at which energy is converted or work is performed. In general, an engine with more power produces more thrust. In addition, the thrust must be greater than drag in order for an aircraft or rocket to accelerate forward for takeoff and to increase its speed during flight. If an aircraft is flying at a constant speed, the amount of thrust will equal drag.

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